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Assessment of Health, Safety and Environment Impact of Flavonoids Derived Demulsifiers

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Abstract:- This paper aims at quantifying the Health, Safety and Environment (HSE) impact of some flavonoid-derived demulsifiers using Chemical Scoring Index (CSI). The CSI is based on the three-hazard categories defined by United Nations' Globally Harmonized System for Classification and Labeling of Chemicals (GHS) for defining greener chemicals. Chemical components of each flavonoid-derived product were quantified by scoring the level of hazard posed by the component in relation to its percentage composition in the product. a carcinogen in a 10% component of a product will be scored higher than in a 1% composition. Additionally, a 'carcinogen' is weighted higher than an 'irritant'. As such, products with low CSI within same usage group are considered to have lower intrinsic hazard and therefore used in selecting best HSE green chemicals. Eight (8) products were quantified; five (5) modified flavonoids and three (3) commercial demulsifiers. 'Modified Flavonoids-A' was considered best HSE chemical with a CSI of '420', while 'Commercial demulsifier-B' was the least HSE chemical with CSI of '1980'. It is recommended that rather than focus on only the performance and cost of a chemical product, it is essential to consider the Health, Safety and Environment impact in the selection of oilfield chemical products. This model will assist HSE professionals in quick assessment of safer chemicals alongside their performance.

Keywords:- *Flavonoids, Demulsifers, Green Chemicals.*

I. INTRODUCTION

In meeting operating performances, large portfolios of chemicals are used by production companies. In oil exploration and production companies in particular, catalogues of chemicals exist for their various operations, namely: drilling, completion, stimulation, workover and production of their wells. Demulsifiers are one of the frequently used chemicals in the oil and gas industries. Demulsifiers comprise of various chemical formulations used in breaking water-in-oil/oil-in-water emulsions.

Emulsion problems in oil and gas industries can lead to high operating/capital cost, corrosion, frequent breakdown of processing units and out of specification products hence must be eradicated. Abedini and Mosayebi(2013), reported that the volume of dispersed water in emulsions, occupies space in the processing equipment and pipelines. Moreso, emulsion causes changes in the characteristics and physical properties of crude oil. Foxenberg et.al (1998) reported that stable water-in-crude oil emulsions, characterized by high viscosity and rigid film can cause significant formation damage to the reservoirs.

Oil and gas companies often make use of chemicals in solving their operational problems and meeting their production goals. They are also under stringent obligations to comply with all legislation set by regulatory authorities, environmental groups and stakeholders.

Oil and Gas companies are mandated to manage all chemicals, products and by-products' hazards to As Low as Reasonably Practicable (ALARP). This means imbibing the culture of Product and Environmental Stewardship.

Verslycke et al (2014), reported that a broad spectrum of chemicals exhibit wide range of potential hazards to human health, physical safety and the environment (HSE). They further, explained that; performance and cost were historically the primary criteria for chemical selection. Sanders et al (2010) also reported that the primary criteria for chemical selection were cost and performance.

The entrance of the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention) in 1990 added criteria for Environmental hazards in product development and selection.

In meeting five (5) of the Sustainable development goals of ; Good health and well-being, Clean water and sanitation, climate action, life below water and life on land, companies and professional have the responsibility of developing safer products by ensuring that HSE standards are prioritized in chemical selection processes. This would in a long run effectively reduce the inherent impacts of these chemicals, meet and exceed our production performances and make the earth conducive for all.

The HSE hazards can be quantified by scoring the various chemical components in each formulation using the three-hazard categories defined by United Nation's Globally Harmonized System for Classification and Labeling of Chemicals (GHS).

Knowing the HSE risks contributed by each chemical component will aid in improving the production and replacement of high HSE risk component with less HSE impacting chemical of same function or with a diluted one.

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Sanders et al (2010), further reported the replacement of three (3) of Halliburton's chemical products through the knowledge of CSI with chemicals of lower HSE risks that performed just as good as the former. CSI rating of hazards helped Halliburton to replace chemicals produced in the 70s and 80s with better and safer chemicals in recent years.

It is worth noting that CSI scores must be equated with price and performance of the product in selecting the qualify candidate for the operation.

This paper documents quantification of HSE hazards in eight(8) demulsifiers. Five(5) of which products were prepared from chemically modified flavonoids (natural products extracted from onions skin wastes), while the other three(3) products were commercial demulsifiers.

The GHS hazard categories and ratings gave the guidelines, while the chemical scoring index was chosen for scoring and ranking each hazard categories. The screening of the three major hazard categories(Physical, Health and Environmental) was carried out for all eight(8) products. The best performing HSE/safe product would be selected based on overall lowest CSI score for all three(3) hazard categories. Thereafter, the best product for the operation will be selected from bottle test result, the product with the highest water dropout; low cost and low HSE impact.

II. METHODOLOGY

Five (5) different demulsifier products derived from modified flavonoids were analysed for their HSE impacts along with three (3) commercial demulsifiers. Major hazards of interest were selected from the three (3) categories of hazards based on GHS (Physical, Health and Environmental). Tables 1.1, 1.2, and 1.3, gives the various categories of Environmental, Health and Physical Hazard criteria respectively in GHS.

The selected hazards of interest and levels were extracted from each chemical component's Safety Data Sheets (SDS). Thereafter a weighted score was assigned from the CSI to each hazard in relation to the percent availability of the chemical component in the measured demulsifier. Tables 2.1, 2.2 and 2.3 give the CSI weighted scores assigned to the health, physical and environmental hazard categories respectively in relation to the percent availability of the chemical component in the measured product.

CSI, assigned weighted scores to various hazards based on the categories, percent composition and level of harm for instance 'carcinogen' is weighted ten times higher than an irritant'.

A computation template is drawn as seen in table 3.0, this is to aid in accurate record of required information from the SDS and appropriately assign the correct score to each component in the products. The scores of each hazard category for all contributing components in a product are then summed up to achieve the CSI for each hazard category in the product.

To calculate the total CSI for HSE risk in a product, the computed values from the physical, environment and health CSIs for the product in question are then added together.

To then select the best demulsifier for the operation, the chemical performance and cost them comes into play amongst the less HSE risk product. To achieve this, 'bottle test' analysis was then carried out, by rating the percent water dropout by each demulsifier on treatment of emulsion from a known field with emulsion problem.

Table 1.1 GHS Basic Environmental Hazard Criteria

Categories	**Category 1**	**Category 2**	**Category 3**
ACUTE AQUATIC TOXICITY			
96hr LC50(for fish)	$\leq$ 1mg/l	>1 but $\leq$ 10mg/l	>10 but $\leq$ 100mg/l
48hr EC50(Crustacea)	$\leq$ 1mg/l	>1 but $\leq$ 10mg/l	>10 but $\leq$ 100mg/l
72hror 96hr ErC50(for Algae or other aquatic plants)	$\leq$ 1mg/l	>1 but $\leq$ 10mg/l	>10 but $\leq$ 100mg/l
CHRONIC AQUATIC TOXICITY			
Chronic NOEC or EC $_X$ (for fish)	$\leq$ 0.1mg/l	$\leq$ 1mg/l	Not Applicable
Chronic NOEC or EC $_X$ (for Crustacea)	$\leq$ 0.1mg/l	$\leq$ 1mg/l	Not Applicable
Chronic NOEC or EC $_X$ (for Algae or other aquatic plants)	$\leq$ 0. 1mg/l	$\leq$ 1mg/l	Not Applicable
OZONE DEPLETION	$\geq$ 0.1mg/l	Not Applicable	
Bioaccumulation Potential	BCF>500 or if absent log Kow > 4		
Rapid Degradability	> 70% in 28days		

Table 1.2 GHS Health Hazard Criteria

Categories	**Category 1**		**Category 2**	**Category 3**	**Category 4**
CARCINOGENICITY ($\geq$ 0.1%)	**CAT 1A (Known)**	**CAT 1B (Presumed)**	**CAT 2 (Suspected)**	NOT APPLICABLE	NOT APPLICABLE
ACUTE TOXICITY					
ACUTE ORAL TOXICITY (mg/kg body weight)	**5**		50	300	2000
ACUTE DERMAL TOXICITY (mg/kg body weight)	50		200	1000	2000
ACUTE INHALATION TOXICITY (Gases(ppmV)	100		500	2500	20000
ACUTE INHALATION TOXICITY (Vapours(mg/l)	0.5		2.0	10	20
ACUTE INHALATION TOXICITY (Dust and Mists(mg/l)	0.05		0.5	1.0	5
CORROSIVITY (IRRITANT)	$\geq$ **5%**		$\geq$ 1% but < 5%	$\geq$ 10%	NOT APPLICABLE

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Table 1.3 GHS Physical Hazard Criteria

Categories	Category 1	Category 2	Category 3	Category 4		
EXPLOSIVE	Division 1.1	Division 1.2	Division 1.3	Division 1.4	Division 1.5	Division 1.6
FLAMMABLE GAS(at 20^{0}C and 101.3kPa)	Ignites in ≤13% mixture with air	Have a flammable range with air mixture	Not Applicable			
FLAMMABLE LIQUID (flash point)	< 23^{0}C; Initial B.pt < 35^{0}C	< 23^{0}C; Initial B.pt >35^{0}C	≥23^{0}C and ≤60^{0}C	> 60^{0}C and ≤ 93^{0}C		Not Applicable
FLAMMABLE SOLID(Burning rate test)	Wetted zone does not stop fire and Burning rate >2.2mm/s	Wetted zone stops fire at least 4mins and Burning rate>2.2mm/s	Not Applicable			
OXIDIZING LIQUID	Mean pressure rise < 1:1 by mass of 50% perchoric acid and cellulose	Mean pressure rise time of 1:1 mixture by mass of 40% aqueous sodium chlorate and cellulose	Mean pressure rise time of 1:1 mixture by mass of 40% aqueous nitric acid and cellulose	Not Applicable		
SELF-REACTIVE SUBSTANCE	Type A	Type B	Type C& D	Type E & F	Type G	
SELF-HEATING SUBSTANCE	+VE test on 25mm sa	-VE test on 25mm but +VE on 100mm sample cube at 140^{0}C	Not Applicable			
EMIT FLAMMABLE GASES IN CONTACT WITH WATER	Reacts vigorously and gas evolution rate of ≥10litres/kg of substance over any 1min	Reacts readily and maximum gas evolution rate of ≥20litres/kg of substance per hour	Reacts slowly and maximum gas evolution rate of ≥1litres/kg of substance per hour	Not Applicable		

Table 2.1 CSI WEIGHTED SCORES FOR HEALTH HAZARDS

Hazard Categories\ Percent Component Available	Maximum CSI Scores	>0%-0.09%	0.1%-0.9%	1%-4.9%	5%-9.9%	10%-29.9%	30%-59.9%	60%-100%
		CSI WEIGHTED SCORES						
NO DATA AVAILABLE	100	10	25	50	75	100	do not evaluate	do not evaluate
CARCINOGENICITY CAT.1	100	25	100	100	100	100	100	100
CARCINOGENICITY CAT.2	75	10	75	75	75	75	75	75
ACUTE TOXICITY CAT.1	100	10	25	50	75	75	100	100
ACUTE TOXICITY CAT.2	75	5	10	25	50	50	75	75
ACUTE TOXICITY CAT.3	50	0	1	5	10	25	50	50
ACUTE TOXICITY CAT.4	10	0	0	1	5	5	10	10
MUTAGENICITY	50	10	25	25	50	50	50	50
REPRODUCTIVE TOXICITY	50	10	25	40	50	50	50	50
ACUTE TARGET ORGAN TOXITY	50	1	5	10	25	25	50	50
CHRONIC TARGET ORGAN TOXITY	50	1	5	10	25	25	50	50
SENSITIZERS	25	5	10	25	25	25	25	25
CORROSIVITY CAT.1	25	0	1	5	5	10	25	25
CORROSIVITY CAT.2(IRRITANT)	10	0	0	0	5	5	10	10
ASPIRATION HAZARD	10	0	0	0	1	5	10	10
NO HAZARD	0	0	0	0	0	0	0	0

Table 2.2 CSI WEIGHTED SCORES FOR PHYSICAL HAZARDS

Hazard Categories\ Percent Component Available	Maximum CSI Scores	>0%-0.09%	0.1%-0.9%	1%-4.9%	5%-9.9%	10%-29.9%	30%-59.9%	60%-100%
		CSI WEIGHTED SCORES						
NO DATA AVAILABLE	50	0	5	10	25	50	Do not Evaluate	Do not Evaluate
EXPLOSIVE	100	25	75	100	100	100	100	100
ORGANIC PEROXIDE	100	5	10	75	75	100	100	100
FLAMMABLE GAS	75	5	10	25	50	75	75	75
FLAMMABLE LIQUID CAT.1	75	0	5	10	25	50	75	75
FLAMMABLE LIQUID CAT.2	50	0	1	5	10	25	50	50
FLAMMABLE LIQUID CAT.3	25	0	0	1	5	10	25	25
FLAMMABLE LIQUID CAT.4	10	0	0	0	1	5	10	10
FLAMMABLE SOLID	75	1	5	50	75	75	75	75
OXIDIZING GAS	75	5	10	25	50	75	75	75
OXIDIZING SOLID	75	1	5	50	50	50	75	75
PYROTECHNIC	75	5	10	25	50	75	75	75
PYROPHORIC(LIQUIDS AND SOLID	75	1	5	10	25	50	75	75
OXIDIZING LIQUID	50	0	1	5	10	25	50	50
SELF-REACTIVE SUBSTANCE	50	0	1	5	10	25	50	50
GASES UNDER PRESSURE	25	1	5	25	25	25	25	25
SELF-HEATING SUBSTANCE	10	0	0	1	1	5	10	10
EMIT FLAMMABLE GASES IN CONTACT WITH WATER	10	0	0	1	1	5	10	10
CORROSIVE TO METALS	5	0	0	1	1	5	5	5
NO HAZARD	0	0	0	0	0	0	0	0

Table 2.3 CSI WEIGHTED SCORES FOR ENVIRONMENTAL HAZARDS

Hazard Categories\ Percent Component Available	Maximum CSI Scores	>0%-0.09%	0.1%-0.9%	1%-4.9%	5%-9.9%	10%-29.9%	30%-59.9%	60%-100%
		CSI WEIGHTED SCORES						
Hazard Categories		>0%-0.09%	0.1%-0.9%	1%-4.9%	5%-9.9%	10%-29.9%	30%-59.9%	60%-100%
NO DATA AVAILABLE	100	10	25	50	75	100	Do not Evaluate	Do not Evaluate
ACUTE AQUATIC TOXICITY CAT.1	100	1	5	10	25	50	75	100
ACUTE AQUATIC TOXICITY CAT.2	75	0	1	5	10	25	50	75
ACUTE AQUATIC TOXICITY CAT.3	50	0	0	1	5	10	25	50
OZONE DEPLETION	50	5	10	50	50	50	50	50
VOLATILE ORGANIC COMPOUNDS	50	5	10	50	50	50	50	50
HAZARDOUS AIR POLLUTANTS	50	1	5	10	25	40	50	50
HAZARDOUS WATER POLLUTANTS	50	1	5	10	25	40	50	50
BIODEGRADATION -Persistent	50	5	10	50	50	50	50	50
BIODEGRADATION- Inherent	10	1	10	10	10	10	10	10
BIOACCUMULATION	50	5	10	50	50	50	50	50
ENDOCRINE DISRUPTORS	50	10	25	50	50	50	50	50
NO HAZARD	0	0	0	0	0	0	0	0

III. RESULTS AND DISCUSSION

The quantified hazard scores of the eight (8) products are shown in Tables 3.1, 3.2, 3.3, 3.4 and figures 1.0, 2.0, 3.0, and 4.0. Table 3.0 is a sample of the computation table, showing the hazard categories and how the various scores for each product were reached. Fig. 5.0 also shows how each hazard categories contributed to the total HSE hazards CIS for each product.

Modified Flavonoid A was calculated as having lowest HSE impact with a total CSI score of '420', while Commercial demulsifier B was calculated as having the highest HSE impact with total CSI score of '1980' as shown in table 3.1, figs.1.0 and 5.0. These scores can be explained that scores increases with increasing number of chemical components that makes up each demulsifier; each adding its contributory factor on the end product.

The reviews of the individual hazard categories contributing to the total HSE risk CSI, played out in a different trend as shown in tables 3.1- 3.4 and figs 1.0 – 5.0. The product with least total HSE CSI score was not necessarily the least in the individual hazard categories. The exception of modified flavonoid A that remained the best in all categories. (This is generally adduced to its fewer chemical components and the components are all derived from natural products).

As show on table 3.2, commercial demulsifier C that ranked sixth(6^{th}) on the overall HSE CSI, became the second(2^{nd}) best performing demulsifier in environmental risks with a environmental CSI score of '200' after modified flavonoid A with CSI of '150'. The low value in commercial demulsifier C can be adduced to main contributing component was defined to be highly volatile and readily biodegradable. The fact remains that one of the limiting factor in CSI computation is insufficient data in the SDS. This limitation affected the environmental computation for Commercial Demulsifier C in being the best because there were no data for some of its components on their SDS, hence high values were slammed on those components as prescribed by CSI guideline.

In same line of reasoning, in table3.4 and fig 4.0, comparison of the physical hazards CSI scores ranked, Commercial Demulsifier B (that was seen as the worst performing in overall HSE impact) second(2^{nd}) with an environmental CSI score of '47' after modified flavonoid A with a CSI of'40'. The major hazard considered in the physical hazard category was flammability because of its high relativity to risk of fire.

On the physical hazard scores for the demulsifiers in Table 3.4 and Fig.4.0, Commercial Demulsifier C was ranked the worst performing on Physical hazards with a score of '85'. This can be adduced to the fact that the most contributory component in the product is defined to be highly flammable in the category 1 scale on GHS. This finding once again proof that CSI ratings corresponds with the hazards effects of each chemical products if appropriately assigned on fair judgment.

On comparison of health hazard scores in Table 3.3 and Fig.2.0, health hazards being the highest contributory hazard to the overall CSI score. A trend was observed that the health risk increased with increased number of chemical components. This could be observed as we progressed from Modified Flavonoid A, through B to C, D and E on Table 3.1. The trend was also applicable for the commercial demulsifiers as seen from the tables that Commercial Demulsifier B with five (5) was obviously higher in hazard score that the ones with four (4) or three(3) components.

It is worth noting that Modified Flavonoids C,D and E though with five(5) chemical components had lower score than the commercial counterpart. This could be adduced to the fact that three(3) out of their five(5) components are natural products extracted from onions skin, cashew shell and corn cob wastes and are defined to be non toxic, hence their minimal health impacts.

In considering the best operational chemical with less HSE risks and excellent performance, demulsification bottle test was carried out. Fig.6 and 7 displayed the effectiveness of each demulsifiers in water seperation from the emulsion at room temperature and 60^0C the average operating condition of a separator in the oilfield. The result showed Modified Flavonoid as the best candidate for the operation.

Table 3.1 TOTAL HSE HAZARDS SCORES

SAMPLE DESCRIPTION	CSI SCORE	POSITION
MODIFIED FLAVONOID A	420	**1ST**
MODIFIED FLAVONOID B	706	**2ND**
MODIFIED FLAVONOID C	732	**3RD**
MODIFIED FLAVONOID D	867	**5TH**
MODIFIED FLAVONOID E	816	**4TH**
COMMERCIAL DEMULSIFIER A	1440	**7TH**
COMMERCIAL DEMULSIFIER B	1980	**8TH**
COMMERCIAL DEMULSIFIER C	946	**6TH**

Table3.2. ENVIRONMENTAL HAZARDS' CSI SCORES

SAMPLE DESCRIPTION	CSI SCORE	POSITION
MODIFIED FLAVONOID A	150	1ST
MODIFIED FLAVONOID B	201	3RD
MODIFIED FLAVONOID C	201	3RD
MODIFIED FLAVONOID D	201	3RD
MODIFIED FLAVONOID E	226	6TH
COMMERCIAL DEMULSIFIER A	235	7TH
COMMERCIAL DEMULSIFIER B	365	8TH
COMMERCIAL DEMULSIFIER C	200	2ND

Table 3.3 HEALTH HAZARDS' CSI SCORES

SAMPLE DESCRIPTION	CSI SCORE	POSITION
MODIFIED FLAVONOID A	230	1ST
MODIFIED FLAVONOID B	455	2ND
MODIFIED FLAVONOID C	481	3RD
MODIFIED FLAVONOID D	616	5TH
MODIFIED FLAVONOID E	540	4TH
COMMERCIAL DEMULSIFIER A	1150	7TH
COMMERCIAL DEMULSIFIER B	1568	8TH
COMMERCIAL DEMULSIFIER C	661	6TH

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Table 3.4 PHYSICAL HAZARDS' CSI SCORES

SAMPLE DESCRIPTION	CSI SCORE	POSITION
MODIFIED FLAVONOID A	40	1ST
MODIFIED FLAVONOID B	50	3RD
MODIFIED FLAVONOID C	50	3RD
MODIFIED FLAVONOID D	50	3RD
MODIFIED FLAVONOID E	50	3RD
COMMERCIAL DEMULSIFIER A	55	7TH
COMMERCIAL DEMULSIFIER B	47	2ND
COMMERCIAL DEMULSIFIER C	85	8TH

Table 3.0: Computation of HSE Hazards and Weighted Scores

PRODUCT	**MODIFIED FLAVONOID B**									**C0MMERCIAL DEMULSIFIER C**						
COMPONENTS	**XX**		**XX**		**XX**		**XX**		**TOTAL CSI**	**XX**		**XX**		**XX**		**TOTAL CSI**
CAS NO.	**XX**		**XX**		**XX**		**XX**			**XX**		**XX**		**XX**		
CONCENTRATION%	**1%**		**0.09%**		**1.40%**		**95-97%**			**40-50%**		**<10%**		**<0.6%**		
ENVIRONMENTAL HAZARD																
ACUTE /CHRONIC AQUATIC TOXICITY	NO DATA	50	24MG/L CAT.3	0	CAT 4	1	1840mg/l CAT.4	0	**51**	28200mg /Lcat.4	25	CAT.2	25	NO DATA	25	75
BIODEGRADATION-	Readiliy degradable (1324mg/mg	0	BOD 46%	0	NO DATA	50	NO DATA	100	**150**	yes	0	NO DATA	75	NO DATA	25	100
		50		0		1		0	**201**		**25**		**100**		**50**	**175**
HEALTH HAZARD																
CARCINOGENICITY	NO DATA	50	CAT.2	10	not present	0	not present	0	**60**	NO DATA	100	NO DATA	75	NO DATA	25	200
ACUTE ORAL TOXICITY	CAT3	5	CAT.2	10	NO DATA	50	CAT.4	10	**75**	CAT. 3	50	NO DATA	75	NO DATA	25	150
ACUTE INHALATION TOXICITY	CAT4	1	CAT.3	1	NO DATA	50	CAT.4	10	**62**	CAT. 3	50	NO DATA	75	CAT.3	1	126
ACUTE DERMAL TOXICITY	CAT4	1	CAT.4	0	NO DATA	50	CAT.4	10	**61**	CAT. 3	50	NO DATA	75	NO DATA	25	150
ACUTE EYE TOXICITY	CAT4	1	CAT.2	10	Cat 2A	25	CAT.1	100	**136**	CAT. 4	10	DATA	75	DATA	25	110
CORROSIVITY	CAT4	1	CAT.2	0	NO DATA	50	CAT.2	10	**61**	CAT. 3	50	NO DATA	75	NO DATA	25	150
		5		31		225		140	**455**		**310**		**450**		**126**	**686**
PHYSICAL HAZARD																
FLAMMABLE LIQUID	NO DATA	10	NO DATA	5	NO DATA	10	CAT.3	25	50	CAT.1	75	CAT.4	5	NO DATA	5	85
	0	**10**		5		10		25	**50**		**75**		**1**		**5**	**85**
Total CSI SCORES	**706**									**946**						

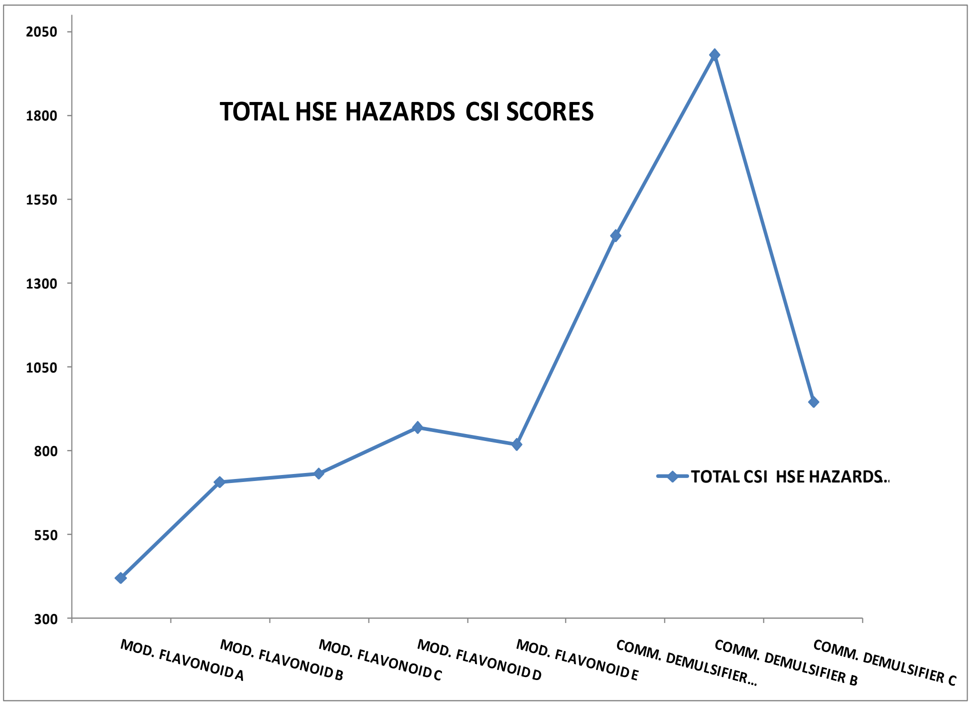

Fig. 1.0. Comparison of Total CSI HSE Hazards Scores

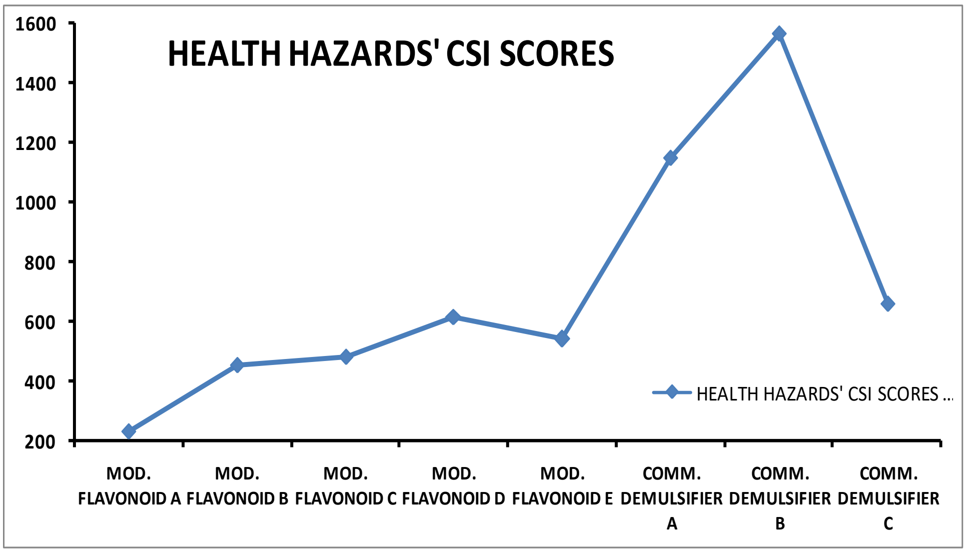

Fig. 2.0. Comparison of Health Hazards' CSI Scores

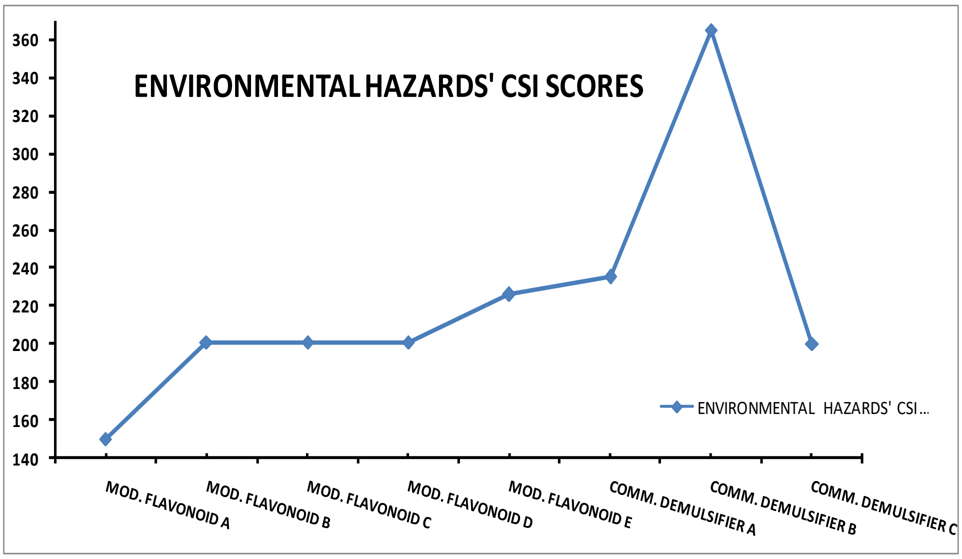

Fig. 3.0 Comparison of Environmental Hazards' CSI Scores

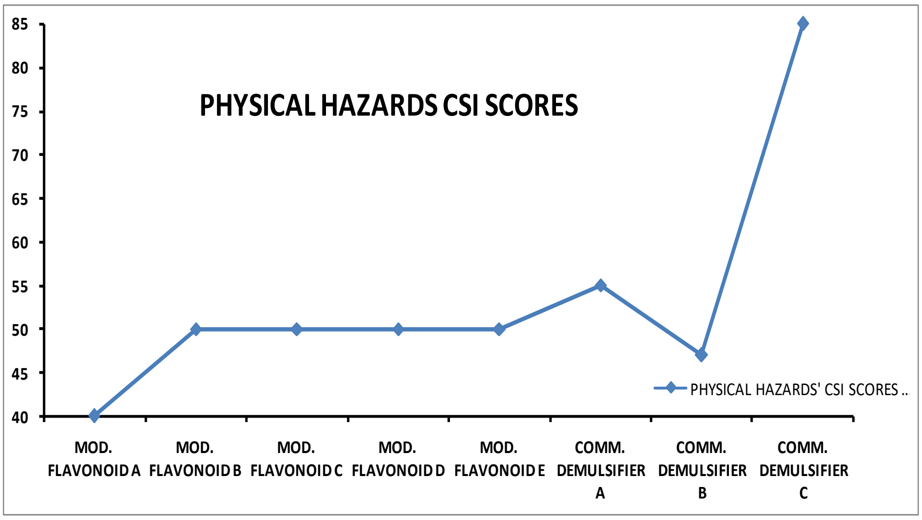

Fig.4.0 Comparison of Physical Hazards CSI Scores

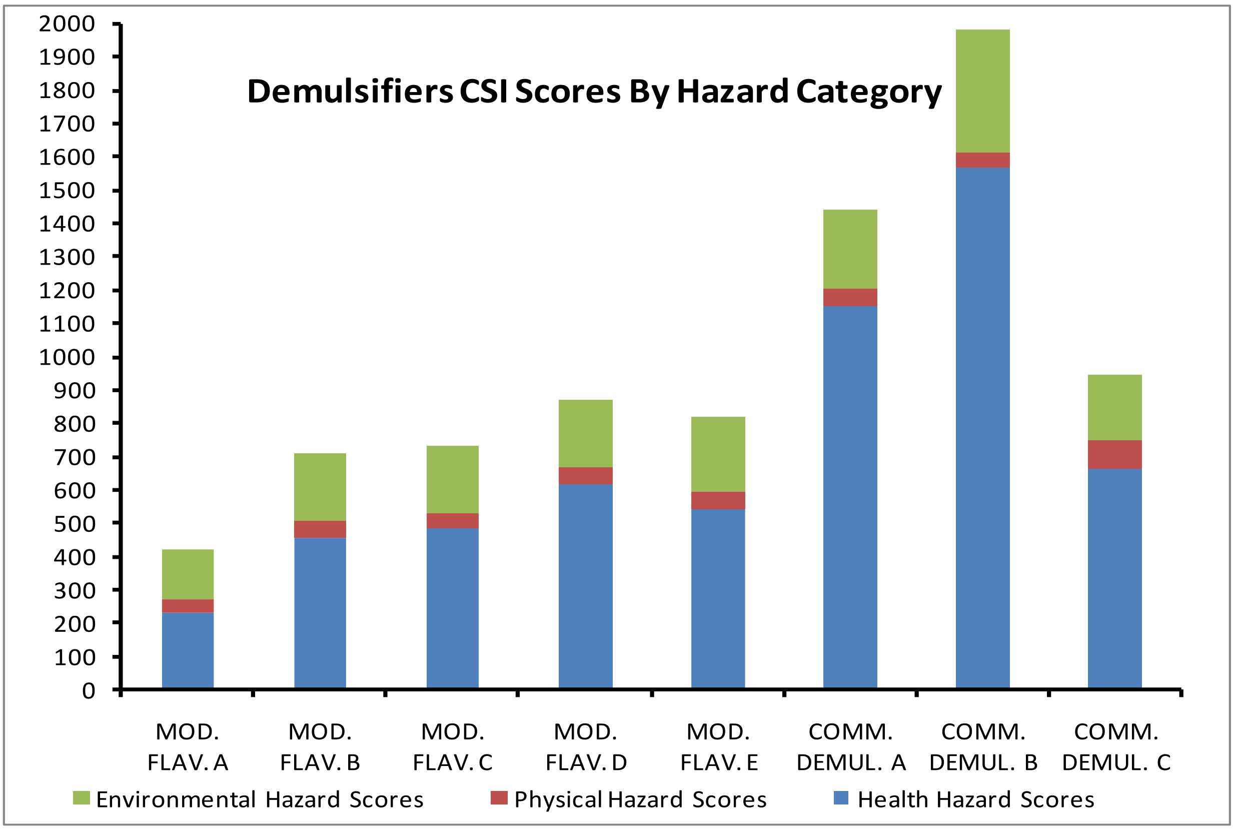

Fig. 5.0 Hazard Categories' Contributions to Total CSI Scores

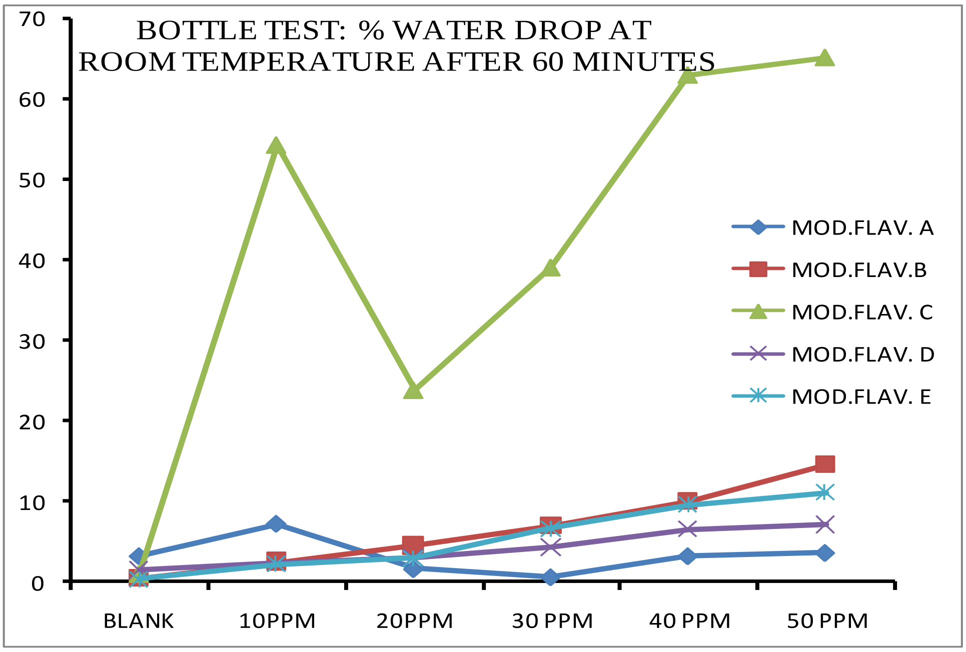

Fig. 6.0 Comparison of Demulsifiers Efficiency at Room Temperature

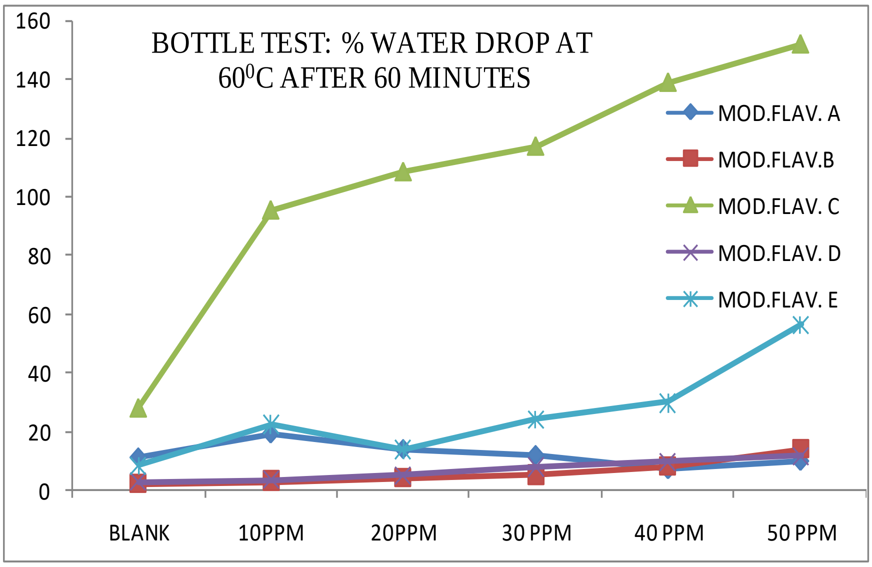

Fig 7.0:- Comparison of Demulsifiers Efficiency at 60^0C

IV. CONCLUSION

In conclusion, it was verified that the Chemical Scoring Index is a valid and reliable method of quantifying HSE hazards inherent in any chemical product. It was observed that the lower the chemical components of the demulsifiers the lesser the HSE impacts.

Quantification of HSE hazards in chemicals will promote selection of HSE performing chemicals and replacement of components with high HSE risks during chemical formulations.

It is worth noting that the best HSE CSI scores might not necessarily be the selected candidate for the operations, selection must always go with effective performance, cost and HSE.

It is important to conclude that, rather than base chemical acceptance on output performance only, the health, safety and environmental impacts of these chemicals should be reviewed.

The major limitation on HSE hazards using the CSI model is incomplete data in most Safety Data Sheets. It is recommended that regulatory bodies should ensure standard and complete safety analysis of produced chemicals.

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